

## AN HERMAPHRODITE ARBACIA

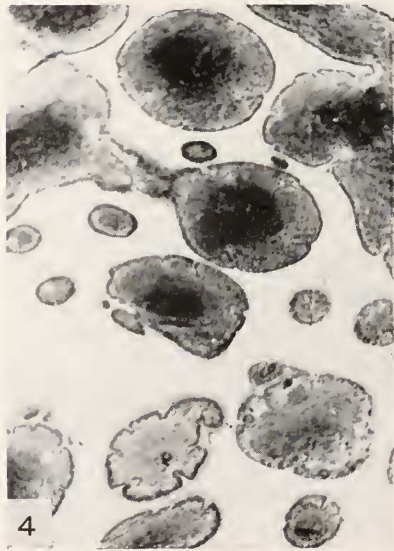
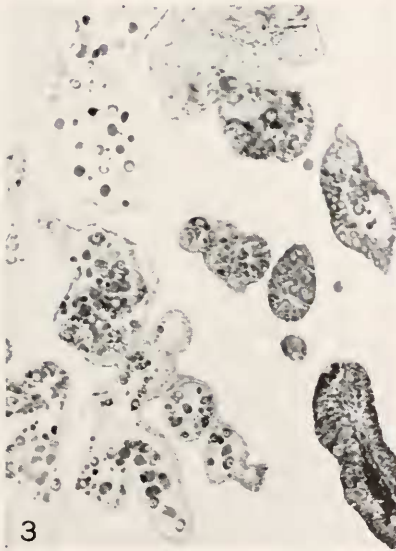
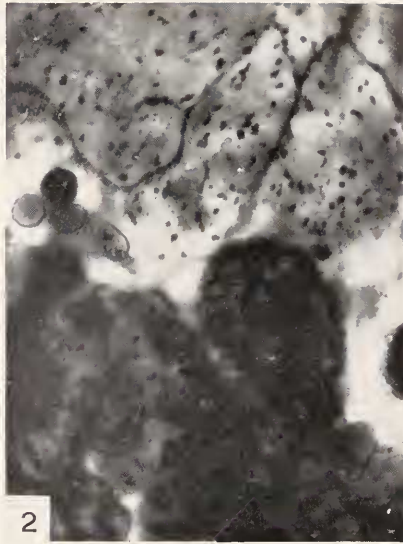
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Among the many thousands of *Arbacia punctulata* opened in the course of ten summers at Woods Hole, and many hundreds of *Arbacia pustulosa*, *Sphaerechinus granularis*, *Paracentrotus lividus* and *Parechinus microtuberculatus* opened during several springs at Naples, and many hundreds of *Strongylocentrotus dröbachiensis*, from Maine, I observed last summer for the first time an hermaphrodite sea urchin, an *Arbacia punctulata*, opened on July 4, 1938. One other case of hermaphroditism in *Arbacia punctulata* has been described by Shapiro (1935); it was found late in the season of 1934 at Woods Hole. His animal had four testes and one ovary. It was fertile *inter se*, and all the eggs formed fertilization membranes, but the cleavages were delayed and abnormal. Many blastulae were obtained and 30 per cent gave rise to gastrulae; there was apparently no further development. James Gray (1921) described a *Strongylocentrotus lividus* in which three of the gonads were completely female, another almost completely so and the fifth contained both eggs and sperm which were fertile *inter se*; development of the eggs is not described. Gadd (1907) described a case of hermaphroditism in *Strongylocentrotus dröbachiensis* at the Mourmanschen Biological Station which had four female gonads and one male, but he does not give any details. The above are the only recorded cases of hermaphroditism in sea urchins, and it is indeed a rare phenomenon.

The hermaphrodite *Arbacia* which I found last summer was quite normal in external appearance and of average size. On removing the ventral portion of the shell, as usual in preparing the eggs, the gonads looked normal except that four were red ovaries and the fifth a white testis with sperm oozing out. Photograph 1 is of the five gonads immediately after removal to sea water. Microscopic observation of the living gonads showed that none of them was entirely male or female. The ovaries had a few tubules containing sperm and the testis contained some ova in various stages of development; that is, the gonads were really ovo-testes but predominantly female or male. A portion of a gonad, living and unstained, is shown in Photograph 2; the ovarian tubules are dark (from the red pigment) and the testis tubules are light with scattered pigment spots; a few eggs have been liberated and lie free in the space between the tubules. A stained

## EXPLANATION OF PLATES



### PLATE I

PHOTOGRAPH 1. Gonads of the hermaphrodite *Arbacia*, immediately after removal from the shell; one testis (white) and four ovaries (black). Note the small piece of testis (white) at edge of the lower right ovary.

PHOTOGRAPH 2. Part of a living gonad, showing testis tubules (white with pigment spots) and ovarian tubules (black) containing eggs, as seen under the microscope. A few eggs are seen free in the space between the tubules.

PHOTOGRAPH 3. Prepared stained section of a gonad predominantly female containing eggs in various stages of maturity. One testis tubule is seen at lower right.

PHOTOGRAPH 4. Prepared stained section of a gonad, predominantly male, containing mostly ripe sperm. One ovarian tubule is seen at lower right.

section of a predominantly female gonad is shown in Photograph 3; all the tubules are filled with eggs in various stages of development except the lower right which is mostly testis. Photograph 4 is a section of the predominantly male gonad; the tubules are all filled with sperm except one at the lower right which contains eggs. Photograph 5 is a section of a predominantly female gonad showing greater detail. Sections of normal ovaries and testes are exactly like these except that there is no mixture. As far as I could tell, especially from a study of the living gonads, the eggs and sperm in the hermaphrodite gonad are separate in the small tubules, and do not lie together without any partition. The eggs are not fertilized until they have been liberated from the tubules into the sea water, probably because the sperm are not motile until in sea water. As soon as the eggs have poured out from the tubules into the sea water, they are immediately fertilized by the sperm which have poured into the sea water and become active. At any one time, therefore, the fertilized eggs are found in various stages of development.

The eggs of the hermaphrodite are perfectly fertile with its own sperm. Normal fertilization membranes are formed, first cleavage takes place normally and at the normal time, and the later cleavages also, and practically all the eggs develop. The only unusual phenomenon was the occurrence of giant eggs. These were about 1 per cent of the total and were all of the same size,  $96\ \mu$  in diameter, giving a volume of  $463,000\ \mu^3$  whereas the normal egg has a diameter of  $74\ \mu$  and a volume of  $212,000\ \mu^3$ ; the giant eggs are approximately twice the normal volume. The origin of the giant eggs is not known, but they do not arise from fusion of ripe eggs since giant immature eggs also occur. I have found similar giant eggs in other *Arbacias* but very rarely, and I have also found in another *Arbacia* normal-sized eggs with giant nuclei. These nuclei measured  $25.6\ \mu$  in diameter giving a volume of  $8,785\ \mu^3$ , whereas the normal nucleus measures  $11.5\ \mu$  in diameter, giving a volume of  $796\ \mu^3$ ; the giant nuclei are thus about eleven times the normal volume.

Eggs in late cleavages ( $3\frac{1}{2}$  hours, and less, after fertilization at

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PHOTOGRAPH 5. Prepared stained section of a gonad under higher magnification to show greater detail. The gonad was predominantly female, but the portion photographed predominantly male.

PHOTOGRAPH 6. Self-fertilized eggs  $3\frac{1}{2}$  hours ( $21^\circ\text{C.}$ ) after opening the animal. Most of the eggs are in late cleavage stages, but some are not so far advanced since they have come from the tubules and been fertilized later than the others. Note the giant eggs, also developing normally.

PHOTOGRAPHS 7-9. Normal development of self-fertilized eggs.

PHOTOGRAPH 7. Very early pluteus, self-fertilized, 31 hours old.

PHOTOGRAPH 8. Pluteus, self-fertilized, 35 hours.

PHOTOGRAPH 9. Pluteus, self-fertilized, 48 hours.

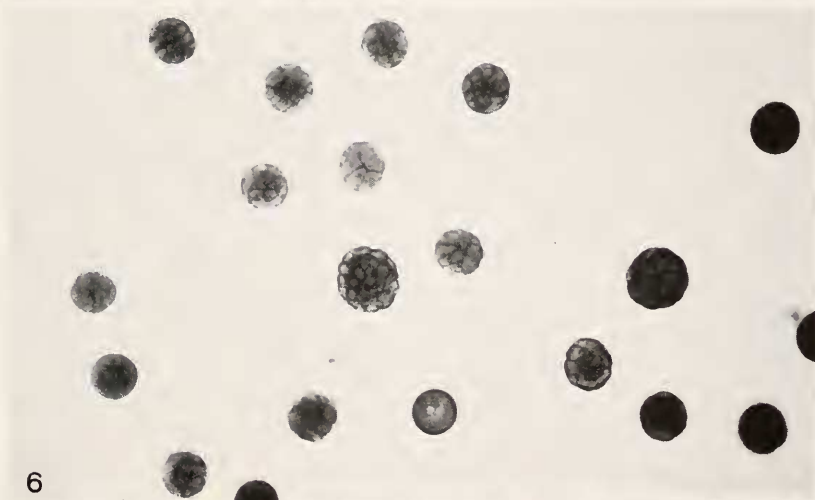


PLATE II



21° C.) are shown in Photograph 6, and one may observe here the giant eggs. The eggs, including the giant ones, develop quite normally and become swimming blastulae at the normal time, 9 hours after fertilization. The blastulae develop into perfectly normal plutei (Photographs 7-9), and these were kept for nine days. The plutei from the giant eggs were indistinguishable from the others which vary greatly in size according to age.

The sperm were perfectly normal in fertilizing other eggs as well as the hermaphrodite eggs (98 per cent), and the eggs from the hermaphrodite could be fertilized perfectly well by sperm from another sea urchin. This latter fact was ascertained by putting a small part of an ovary into fresh water for about  $\frac{1}{2}$  minute to kill the sperm on the outside; then the ovary was transferred to sea water. After an hour, only 1 per cent of the eggs shed were fertilized (by a few sperm liberated from the ovotestis after washing). But when the shed eggs were transferred to sea water containing sperm from another animal, 98 per cent were fertilized. The fertilization was therefore made by the sperm of the normal animal. These eggs developed quite normally. The hermaphrodite animal is therefore fertile with other males and females as well as *inter se*.

I think this the first recorded case in which the eggs of an hermaphrodite sea urchin, self-fertilized, developed absolutely normally to perfect plutei.

#### SUMMARY

1. A rare case of perfect functional hermaphroditism in the sea urchin *Arbacia punctulata* is described. There were four red gonads predominantly female and one white gonad predominantly male; there were a few tubules of the opposite sex in all the gonads.

2. Fertilization occurred as soon as the sexual products were liberated in sea water.

3. The development of the self-fertilized eggs was absolutely normal, in time and morphology, and normal plutei were raised, nine days old.

4. There occurred about 1 per cent of giant eggs; these were twice the normal volume, and they also developed normally.

5. Both the eggs and the sperm also functioned perfectly normally with other normal males and females.

#### LITERATURE CITED

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